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Scott P. Barnes and Edward F. Miller
Lewis Research Center
Cleveland, Ohio

NASA
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and Space Administration

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1978

CARRIER-INTERFERENCE RATIOS FOR FREQUENCY SHARING BETWEEN FREQUENCY-MODULATED AND AMPLITUDE-MODULATED - VESTIGIAL-SIDEBAND TELEVISION SYSTEMS

by Scott P. Barnes and Edward F. Miller

Lewis Research Center

SUMMARY

A knowledge of television protection ratios (the ratio of wanted signal power to interfering signal power at the receiver) as a function of assessed picture quality is vital for planning television systems. With the increasing use of frequency-modulated (FM) television transmissions from satellites at and near frequencies allocated for terrestrial, amplitude-modulated - vestigial-sideband (AM-VSB) television transmissions, and other FM television satellite transmissions, the protection ratios required between these systems must be known.

This report presents measurements of protection ratios required to produce just perceptible interference (1) in an FM television system being interfered with by another FM television signal, (2) in an FM television system being interfered with by an AM-VSB television signal, and (3) in an AM-VSB television system being interfered with by an FM television signal. The effect of varying the frequency deviation of the FM signal is discussed, as is the effect of the choice of subject material on measurements of this type. Tests were performed under the test conditions and using test slides suggested by the Consultative Committee on International Radio (CCIR).

Results of these tests indicate that, for an FM television system being interfered with by another FM television signal at approximately the same frequency, the average signal power of the wanted signal should be 26 to 37 decibels higher than the average signal power of the interfering signal. For an AM-VSB television signal interfering with an FM television system, the sync peak average power of the AM-VSB television signal should be 18 to 31 decibels below the average signal power of the FM television signal for just perceptible interference to the FM television system. For an FM television signal interfering with an AM-VSB television system, the wanted AM-VSB television's sync peak average power should be 56 to 59 decibels above the average power of the interfering signal. The range of power ratios occurs as a result of different TV scenes used in the tests and different FM-signal frequency deviations used. All tests were performed using 525-line, system M, color television signals.

INTRODUCTION

The efficient use of the frequency spectrum by television transmission systems (in both the broadcasting service and the fixed service) requires careful planning to avoid objectionable interferences. A key element in such planning is the interference protection ratio (the ratio of wanted-to-unwanted signal power at the receiver input) as a function of subjectively assessed picture quality. The planning of the very high frequency (VHF) and ultrahigh frequency (UHF) terrestrial television systems was based on long-established protection ratios for interference between two amplitude-modulated-vestigial-sideband signals (AM-VSB) (ref. 1). Present frequency allocations for communications satellites allow for interferences between several modulation formats for television signals, such as frequency modulation (FM), digital modulation, and AM-VSB.

For a variety of reasons television transmissions from synchronous orbit to the Earth are likely to be frequency modulated. In the 620- to 790-megahertz frequency band, which is allocated for both space broadcasting and terrestrial television broadcasting in the United States, interference between AM-VSB and FM systems is quite possible. Similarly, the same interference is likely in the 2500- to 2690-megahertz band. The 11.7- to 12.2-gigahertz band is allocated to both the broadcasting-satellite and the fixed-satellite services. Thus, in this band, interference between FM systems is likely both within each service and between the services.

The current data and conclusions on interference protection ratios for television are best summarized in reference 2. Also, the Final Acts of the 1977 World Administrative Radio Conference (ref. 3) present summarizing curves based on protection-ratio measurements by several organizations. A continuing difficulty in the determination of protection ratios for international frequency planning has been the reconciliation of test results obtained under different test conditions and with different video test scenes. These tests require subjective evaluation of picture impairments and cover a wide range of test parameters. Consequently, any series of tests includes only a portion of the entire set of needed measurements. To coordinate television protection-ratio measurements, the CCIR established the Interim Working Part (IWP) 11/2 (ref. 4), which set out to (". . . agree upon . . . a standardized set of test conditions and measurement procedures for the determination of protection ratios . . . ," and "encourage administrations to participate in a coordinated program of measurements . . . ."

In May 1976 the IWP 11/2 met and drafted a new report (ref. 5) which discussed the test conditions and signal characteristics necessary to standardize the measurement of television protection ratios. The report urged the performance of tests at the "reference-case" conditions given in reference 2 and the use of four test slides considered suitable for interference tests. The recently completed CCIR Final Meetings (Geneva, Sept.-Oct. 1977) continued the advocacy of reference-case test conditions (refs. 6 and 7).

This paper presents the results of television-protection-ratio tests performed in the United States using the reference-case conditions and the suggested test slides. The results of these subjective tests are presented for interference to an FM television system by both FM and AM-VSB television systems. Also presented are results for AM-VSB television systems with interference from an FM television system. All measurements were made using system M, 525-line television standards. The suggested test slides and another standard test signal were used, and the reference-case conditions were followed except in regard to the number of viewers used in the tests.

In these tests the effect of different FM-receiver filter characteristics were also examined. In addition, tests were performed using an FM-modulation index different from the reference-case modulation index to determine the effect of this parameter.

APPARATUS

A summary of some of the conditions established by the IWP 11/2 which might affect interference assessments are given below:

(1) Television standards and color system

(2) FM signal characteristics:

 Deviation (peak to peak), 12 MHz

 Pre-emphasis, as recommended in CCIR Recommendation 405

 Modulation sense, sync at lower frequency

(3) Applicable television standards for AM-VSB television systems

(4) Video signal to unweighted noise ratios of 36 dB or greater

(5) Line synchronization to place the sync bars of the interfering signal within the wanted picture

(6) Viewing conditions as given in CCIR Recommendation 500 (ref. 8) with a minimum of 10 to 20 viewers

(7) A five-level picture-impairment scale to rate impairments (as given in Recommendation 500). An impairment level of 4.5 is to be used in the tests.

All the reference-case conditions were used except for the number of viewers judging the perceptibility of interference: Instead of the 10 to 20 viewers called for, a single viewer performed the evaluations. This affects the impairment level at which the tests are performed. The reference-case conditions specify that measurements be made at an impairment level of 4.5, midway between level 5 (imperceptible interference), and level 4 (perceptible, but not annoying interference). When there are several viewers, a picture is graded 4.5 when the mean impairment grade is 4.5. This guarantees that at least 50 percent of the viewers tested will rate the picture grade 5. For the measurements presented in this report, a single, expert viewer judged the pictures according to the criteria of just perceptible interference. This was accomplished by beginning at a

power ratio that produced visible interference and increasing the power difference in 1-decibel steps until any further increase would cause the interference to become imperceptible. Using this technique should produce an impairment level between 4 and 5, the exact level being indeterminable. This approach is a practical way to achieve a grade between 4 and 5 when using a single viewer. Because of the wide range of parameters investigated (frequency offset, different frequency deviations, several receiver-filter bandwidths and types of filters, and different modulation techniques) it was not practical to use enough viewers to obtain a statistical impairment grade.

Test Setup - FM Television Interfering with FM Television

The test setup used for measuring protection ratios for the case of an FM television signal interfering with another FM television signal is shown in figure 1.

The sources of NTSC (National Television Standards Committee) type of video and audio base-band signals for both the wanted and interfering signals are video tape recorders. These base-band signals modulate FM transmitters - a 6.4-gigahertz transmitter for the wanted signal and a 12-gigahertz transmitter (tunable ±100 MHz) for the interfering signal. The 12-gigahertz interfering signal is translated down to approximately 6.4 gigahertz using a mixer and a local oscillator. A portion of this signal is coupled to a frequency counter, and the remainder passes through two adjustable step attenuators to a coupler used to combine the wanted and interfering signals. A portion of this combined signal is coupled to a spectrum analyzer, and the remainder passes to the fixed-tuned, 6.4-gigahertz FM receiver. The base-band video signal from the receiver is displayed on a 63.5-centimeter (25-in.) monitor.

Audio subcarriers were present on both the wanted and interfering signals, but audio quality was not evaluated. The power ratios required for just perceptible interference were evaluated for several conditions using this setup. Measurements were made with FM deviations (peak to peak) of 12 and 18 megahertz. With a peak-to-peak deviation of 12 megahertz, protection ratios were evaluated using two intermediate frequency (IF) filters: One is a four-section, Chebyshev filter with a 3-decibel bandwidth of 22 megahertz; and the other is a six-section, Chebyshev filter with a 3-decibel bandwidth of 21 megahertz. With peak-to-peak deviations of 18 megahertz, a six-section, Chebyshev filter with a 32-megahertz, 3-decibel bandwidth is used. Plots of the IF response of the receiver with these filters are shown in figure 2.

The base-band video signal used to modulate the wanted signal was also varied to allow measurements of protection ratios for a range of subject material. Four test slides chosen by CCIR IWP 11/2 as being representative of critical TV scenes were used. An electronically generated color-bar test signal was also used. The base-band video and audio used to modulate the interfering signal was a recorded program from commercial

television broadcasts. The ratio of the wanted FM signal power to interfering FM signal power for just perceptible interference, $R_{FM/FM}$, is given by

$$R_{FM/FM} = \frac{P_{av(FM - wanted)}}{P_{av(FM - interfering)}}$$

Test Setup - AM Television Interfering with FM Television

The test setup used for measuring protection ratios for the case of an AM-VSB television signal interfering with an FM television signal is shown in figure 3. The interfering AM-VSB television signal is generated by modulating a channel 10 (192 to 198 MHz), AM-VSB television modulator with NTSC video and audio base-band signals from a video-tape recorder. This signal is translated up to approximately 12 gigahertz using a mixer and a local oscillator, which is tunable about a center frequency of 11.8 gigahertz. The interfering signal is then translated down to approximately 6.4 gigahertz, passes through two adjustable step attenuators, and is combined with the wanted signal from a 6.4-gigahertz FM transmitter. A portion of this signal is coupled to a spectrum analyzer; the remainder passes to a fixed tuned, 6.4-gigahertz FM receiver. The power ratios required for just perceptible interference were measured for peak-to-peak FM deviations of 18 and 12 megahertz. With an FM deviation of 12 megahertz, protection ratios were measured using two different IF filters in the receiver (IF response shown in fig. 2).

The ratio of wanted FM signal power to the AM-VSB signal power for just perceptible interference, $R_{FM/AM}$, is given by

$$R_{FM/AM} = \frac{P_{av(FM\text{-}wanted)}}{P_{sync\ pk\ av(AM\text{-}interfering)}}$$

Test Setup - FM Television Interfering with AM Television

The test setup used for measuring protection ratios for the case of an FM television signal interfering with an AM-VSB television signal is shown in figure 4. The interfering FM signal is generated by modulating a tunable, 12-gigahertz FM transmitter with video and audio from a video tape recorder. The signal frequency is translated to approximately 66 megahertz, is passed through two adjustable step attenuators, and is combined with the AM-VSB television signal from a channel 4 (66 to 72 MHz)

modulator. A portion of this signal is coupled to a spectrum analyzer; the remainder is demodulated by an AM-VSB television tuner. The IF response of the AM tuner is illustrated in figure 5. Measurements of power ratios required for just perceptible interference were made for FM deviations of 18 and 12 MHz. The ratio of wanted AM-VSB signal to FM signal power for just perceptible interference, $R_{AM/FM}$, is given by

$$R_{AM/FM} = \frac{P_{sync\ pk\ av(AM\text{-}wanted)}}{P_{av(FM\ -\ interfering)}}$$

TEST PROCEDURES

The base-band video resulting from the demodulation of the signal composed of the wanted and interfering signals was displayed on a 63.5 centimeter (25 in.) monitor. A single, expert viewer judged the perceptibility of the interference in a partially darkened room at a distance of approximately five times the screen height.

For the measurements presented just perceptible interference is defined as interference, so slight, that any reduction in the power level of the interfering signal would cause the interference to become imperceptible. The just perceptible interference criteria does not attempt to evaluate the annoying effect of interference, but only establishes the threshold of perceptibility.

Five base-band video signals were used to modulate the wanted signal. Four of these are test slides chosen by the Interim Working Party 11/2 as being representative of critical scenes: Two are from the Society of Motion Picture and Television Engineers' (SMPTE) color reference slide series (Nos. 1 and 14), and two are from the Philips test slide series for color television (Nos. 8 and 14). An electronically generated, split-screen, color-bar test signal was also used. Black and white photographs of the four, color test slides are shown in figure 6. The interfering signal was modulated by a video tape recording of a commercial television program.

The signal to unweighted noise ratio of the base-band video modulating the wanted signal was 48 decibels for the four test slides and was 55 decibels for the color-bar test signal. The signal to unweighted noise ratio of the link, comprising the modulator, demodulator, and the hardware between the two, was 47 to 54 decibels. Thus, the signal to unweighted noise ratio of the demodulated video being evaluated was between 44.5 and 47.0 decibels for the slides and between 46.4 and 51.5 decibels for the color-bar test signal. The variation of the link signal to unweighted noise ratio is due to measurement accuracy (±2 dB) and the effect of the modulation schemes used. The signal-to-noise ratio for all test conditions exceeded the 36-decibel minimum value

given in the reference case.

Synchronization was established between the wanted and interfering base-band signals to put the vertical and horizontal sync bars near the center of the picture.

The frequency-modulated signals were operated with pre-emphasis and with a 7.5-megahertz audio subcarrier added to the base-band signal. For the wanted signal the ratio between the power in the video carrier to that in the first side band of the audio subcarrier was 26 decibels. For the interfering signal this ratio was 21 decibels. The peak-to-peak deviation of the audio subcarrier by the audio programming was approximately 200 kilohertz. The sense of modulation for the FM television signals was such that a black to white transition corresponds to an increase in the instantaneous frequency. The ratio of the power of the AM-VSB-television video carrier to the power of the audio carrier was 10 decibels.

The protection ratios versus frequency offset were measured by setting the desired frequency offset between the wanted and interfering signals and varying (with step attenuators) the power of the interfering signal coupled to the demodulator. Frequency offsets of up to 30 megahertz, or approximately equal powers of the wanted and interfering signals, were the limits of the measurements.

MEASUREMENT ACCURACY

The measurements of protection ratios versus frequency offsets are subject to small errors as a result of the limitations of the equipment used for measure. The uncertainties in determining protection ratios and frequency offsets are summarized in table I.

For the tests with an FM signal interfering with another FM signal, a frequency counter was used to measure frequency offset. Errors with this setup are ±0.1 megahertz. For the other setups a spectrum analyzer was used to measure frequency offset. The uncertainty in measurements using this method is ±0.25 megahertz. The FM signals were centered in the pass band of the receiver. The accuracy of this adjustment is ±2 megahertz.

Power-ratio measurements presented are subject to small errors. Common to all setups are the errors in equalizing the powers of the wanted and interfering signals using the spectrum analyzer (±0.4 dB) and errors due to the step attenuators. The 0- to 9-decibel step attenuator has an accuracy of ±0.4 decibel and the 0- to 60-decibel step attenuator has an accuracy of ±1.3 decibel.

In addition to these errors, $R_{FM/FM}$ is subject to an error due to the nonuniform gain of a mixer (±0.4 dB). The protection ratio $R_{FM/AM}$ is subject to errors in the conversion from AM carrier power (the parameter measured in the tests) to AM sync peak average power, which errors are estimated to be 0 to -0.2 decibel for conversion

from AM carrier power to average video power and ±0.75 decibel for conversion from average video power to AM sync peak average power.

The ratio $R_{AM/FM}$ is subject to similar conversion errors, estimated to be 0 to -0.4 decibels and ±0.75 decibels.

RESULTS AND DISCUSSION

FM Television Interfering with FM Television

The procedures and test setups outlined in the previous sections were used to determine the protection ratios $R_{FM/FM}$ required for just perceptible interference as a function of frequency offsets. Figure 7 describes the results when peak-to-peak FM deviations of 18 megahertz are used for both the wanted and interfering signals. The receiver filter is a six-section Chebyshev filter. Figure 8 describes the results for peak-to-peak FM deviations of 12 megahertz and a four-section Chebyshev filter in the receiver. Figure 9 describes the results when a six-section Chebyshev filter is used in the receiver.

Of major interest in these results are the peak protection ratios required for just perceptible interference and the average protection ratios required when the carrier frequencies are equal, or nearly so (cochannel). These results are summarized in table II for the test configurations and the subject material (color-bar test signal or test slides) used. The peaks in the protection ratio as a function of frequency offset plots occur because of an increased sensitivity of the wanted system to interference at particular frequency offsets. As discussed in the introduction, many organizations have made similar measurements, but at varying test conditions. Reference 2 presents a formula for predicting protection ratios based on impairment grade, television system, and FM modulation index. The formula is

$$PR_o = C - 20 \log\left(\frac{D_v}{12}\right) - Q + 1.1\, Q^2$$

where D_v is the nominal peak-to-peak frequency deviation; Q is the impairment grade, which concerns the effect of interference only and is measured on the five-point scale recommended in reference 8; and C is a constant, whose value depends on the television standard (13.5 for a 525-line, standard M). Because the exact impairment grade at which these present tests were performed cannot be determined (it is only known that the impairment grade is between 4 and 5), only a gross check of the overall formula is possible. The formula predicts that for peak-to-peak FM deviations of 12 megahertz, a

protection ratio of 27 decibels is needed for an impairment grade of 4 (perceptible, but not annoying, interference) and a protection ratio of 36 decibels is needed for an impairment grade 5 (imperceptible interference). Examination of the results of the experiments described in this report with FM deviations of 12 megahertz show that the range of protection ratios required for the test slides are between these values and that the protection ratios required when using the color-bar test signal are at the high end, or slightly above, this range.

When using peak-to-peak FM deviations of 18 megahertz, the formula predicts that protection ratios will be 3.5 decibels less than those predicted when using FM deviations of 12 megahertz. Comparison of the data in table II shows a difference in protection ratios close to this value. The average cochannel protection ratios when using 18-megahertz FM deviations are 2 to 4 decibels less than those when using 12-megahertz FM deviations.

The effect of the subject material can be seen in table II and figures 7 to 9. The average cochannel protection ratios required for the color-bar test signal are 6 to 7 decibels higher than required for the four-color test slides. The differences in the peak protection ratios observed are 4 to 7 decibels.

A comparison of the results for 12-megahertz FM deviation using four- and six-section receiver filters shows that the average cochannel protection ratios were 1 to 2 decibels less and that the peak protection ratios observed were 1 to 4 decibels less, when using the six-section receiver filter. For frequency offsets greater than about 10 megahertz, the protection ratios required when using the six-section receiver filter are generally less than the protection ratios required when using the four-section receiver filter.

AM-VSB Television Interfering with FM Television

Figure 10 gives the measured protection ratios $R_{FM/AM}$ required for just perceptible interference as a function of carrier offset when the wanted signal is an FM television signal with a peak-to-peak deviation of 18 megahertz and the interfering signal is an AM-VSB television signal. Figure 11 describes the results for a peak-to-peak FM deviation of 12 MHz and a four-section Chebyshev filter in the receiver, and figure 12 describes the results for a six-section Chebyshev filter in the receiver.

The peak protection ratios required for just perceptible interference and the average protection ratios required when the carrier frequencies are equal, or nearly so (i.e., cochannel), are summarized in table III. The effect of a change in FM deviation can be seen in table III. The average cochannel protection ratios for an 18-megahertz FM deviation are 4 decibels less than those for a 12-megahertz FM deviation. This supports the suggestion of an approximately 20 $\log(D_v/12)$ relationship (ref. 2).

The effect of the subject material used in the tests can be seen in table III and figures 10 to 12. The color-bar test signal requires average cochannel protection ratios that are 7 decibels higher than those that the four test slides require. The differences in the peak protection ratios observed are 8 to 10 decibels.

A comparison of the results observed when using an FM deviation of 12 megahertz and four- and six-section receiver filters shows that the protection ratios required for frequency offsets of greater than 10 megahertz are generally less with the six-section filter than with the four-section filter. The comparison also shows that the number of sections in the filter has little or no effect on the average cochannel or the peak-protection ratios.

FM Television Interfering with AM-VSB Television

Figures 13, 14, and table IV describe the protection ratios $R_{AM/FM}$ required for just perceptible interference as a function of carrier offset when the wanted signal is an AM-VSB TV transmission and the interfering signal is an FM TV signal.

The highest protection ratios generally occurred when the carrier frequencies were equal and when the carrier frequency of the interfering FM signal was approximately 3 megahertz above the AM carrier frequency (at approximately the color subcarrier frequency). In the latter case, the interference was most pronounced when the colors in the subject material were saturated.

Reference 2 used protection ratios obtained by other organizations under various test conditions and, after choosing a set of reference test conditions, extrapolated the protection ratios to obtain values at these reference conditions. The protection ratio required for equal and nearly equal (±5 MHz) carrier frequencies was 50 decibels. Although this value is significantly different from the peak value measured in these tests, it is close to values from reference 9 for system M, with no pre-emphasis and 18-megahertz peak-to-peak frequency deviation.

Two factors that may account for this difference are the absence of pre-emphasis in the previous tests used by the CCIR, and the choice of subject and interfering material. The interfering program material used in the tests described in this report was a program recorded from commercial television, which was composed mostly of saturated colors. If interaction between the color subcarriers produces interference, the test material with the most saturated colors should require the highest protection ratios. The color-bar test signal and Philips test slide 8 are composed mostly of saturated colors, and do, in fact, require the highest protection ratios; the SMPTE test slide 1 contains the fewest saturated colors and requires the lowest protection ratios. One of the tests used by the CCIR (ref. 10) used SMPTE test slide 1 as the interfering modulation, with SMPTE test slide 14 as the wanted subject material. Another test (ref. 9)

used a moving commercial television program as the wanted signal, which contained an unknown amount of saturated colors. If the level of the color subcarrier of the interfering signal is significant, the addition of pre-emphasis, which attenuates the low-frequency components and amplifies the higher frequency components of the base-band signal, might account for the difference in the results of the tests.

As shown in table IV and figures 13 and 14, the dependence of protection ratios on the FM deviation of the interfering signal is slight. The protection ratios required when using an FM deviation of 12 megahertz are 1 to 2 decibels higher than those required when using a FM deviation of 18 megahertz.

The difference between the protection ratios required for the color bar test signal as compared with the four test slides is 1 to 2 decibels.

Effect of Subject Material

In the preceding tests the protection ratios measured when using SMPTE slide 1 were generally significantly less than those measured when using the other three test slides. Except for the tests with FM television interfering with FM television (with 12-MHz, peak-to-peak, deviations), the peak protection ratios measured when using SMPTE slide 1 were 3 to 7 decibels below those measured when using the other three test slides. In no case were the peak protection ratios measured when using SMPTE test slide 1 higher than those measured when using one of the other test slides. On the basis of these tests, it appears that SMPTE slide 1 is not "a reasonably critical still picture." The other three test slides required approximately the same protection ratios, which were, in general, significantly higher than those measured when using SMPTE slide 1.

SUMMARY OF RESULTS

The television protection ratio tests performed according to the reference condition guidelines suggested by the Consultative Committee on International Radio (CCIR) have produced the following results, for system M format, color-slides as the wanted signals, and just perceptible interference as judged by a single expert viewer.

Wanted signal	Unwanted signal	Average cochannel protection ratio, dB
FM, 12-MHz deviation	FM, 12-MHz deviation	[a]29
FM, 18-MHz deviation	FM, 18-MHz deviation	[a]26
FM, 12-MHz deviation	AM-VSB	[a]22
FM, 18-MHz deviation	AM-VSB	[a]18
AM-VSB	FM, 12-MHz deviation	57
AM-VSB	FM, 18-MHz deviation	56

[a]Averaged for both four- and six-section receiver filters.

The cochannel protection ratios measured for an FM television signal interfering with another FM television signal agree quite closely with, and thus substantiate, prior extrapolations to the reference-case conditions (ref. 2). Also, the decrease in FM protection ratio (ref. 2) by the approximate term of 20 $\log(D_v/12)$ is substantiated by the measurements for both FM and AM-VSB as the interfering signal. For FM television, tests using a standard color-bar test signal as the wanted signal required protection ratios up to 7 decibels greater than the same tests using the selected slides as the wanted scenes. In the case of AM-VSB television as the wanted signal, the measured protection ratio against FM television signals exceeded prior measurements by approximately 8 decibels. The difference is attributed to the pre-emphasis used on the FM system in the present measurements and to the color content of the test slides and the interfering signals.

Tests with four- and six-section filters in the FM receiver showed the sharper filter to require a lower protection ratio for frequency offsets greater than 10 megahertz.

Three of the test slides used for the wanted picture resulted in similar protection ratios: slides 8 and 14 of the Philips test slide series for color television and slide 14 of the Society of Motion Picture and Television Engineers (SMPTE) color reference slide series. The fourth slide (SMPTE 1) was in most cases substantially less critical (3 to 7 dB).

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TABLE I. - ERRORS IN MEASURED PARAMETERS

Measured parameter	Maximum error	rms error
$R_{FM/FM}$	±2.5 dB	1.5 dB
$R_{FM/AM}$	+2.9 dB/-3.1 dB	1.6 dB
$R_{AM/FM}$	+2.9 dB/-3.3 dB	1.6 dB
$\Delta f_{FM/FM}$	±0.1 MHz	0.1 MHz
$\Delta f_{FM/AM}$	±0.25 MHz	0.25 MHz
$\Delta f_{AM/FM}$	±0.25 MHz	0.25 MHz

TABLE II. - CO-CHANNEL PROTECTION RATIOS REQUIRED FOR JUST PERCEPTIBLE INTERFERENCE FOR FM TELEVISION INTERFERING WITH FM TELEVISION

Subject signal	12-MHz FM deviation				18-MHz FM deviation	
	4-Section receiver filter		6-Section receiver filter			
	Protection ratio, dB					
	Peak	Average	Peak	Average	Peak	Average
Color bar	37	36	36	35	33	32
Test slides[a]	33	30	29	28	28	26

[a]Four slides.

TABLE III. - CO-CHANNEL PROTECTION RATIOS REQUIRED FOR JUST PERCEPTIBLE INTERFERENCE FOR AM-VSB TELEVISION INTERFERING WITH FM TELEVISION

Subject signal	12-MHz FM deviation				18-MHz FM deviation	
	4-Section receiver filter		6-Section receiver filter			
	Protection ratio, dB					
	Peak	Average	Peak	Average	Peak	Average
Color bar	31	29	31	29	29	25
Test slides[a]	23	22	23	22	19	18

[a]Four slides.

TABLE IV. - PEAK PROTECTION RATIOS REQUIRED FOR JUST PERCEPTIBLE INTERFERENCE FOR FM TELEVISION INTERFERING WITH AM-VSB TELEVISION

Subject signal	12-MHz FM deviation	18-MHz FM deviation
	Protection ratio, dB	
Color bar	59	57
Test slides[a]	57	56

[a]Four slides.

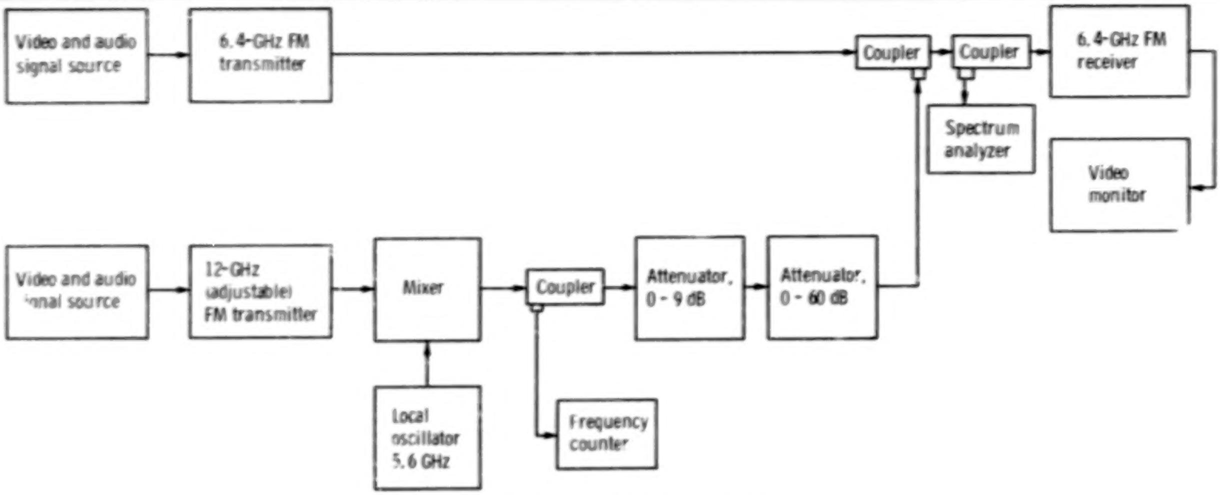
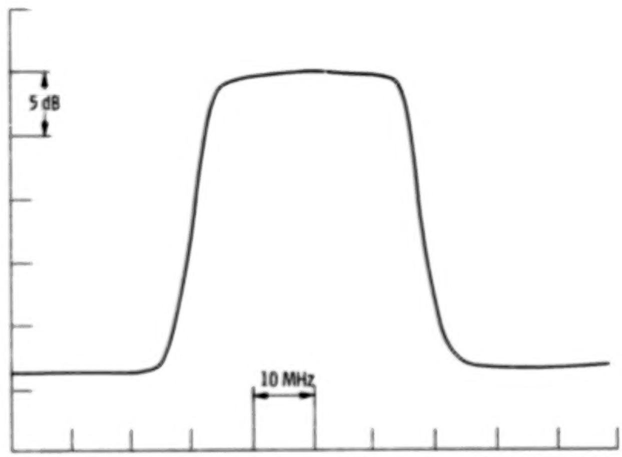
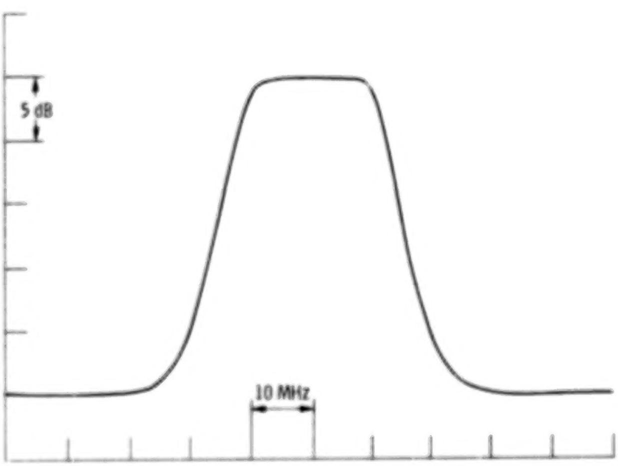


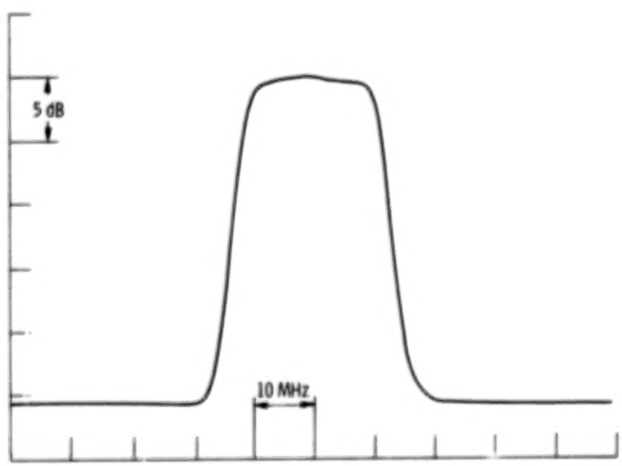
Figure 1. - FM television interfering with FM television.



(a) Filter type, six-section Chebyshev; center frequency, 130 MHz; bandwidth (3 dB), 32 MHz.



(b) Filter type, four-section Chebyshev; center frequency, 130 MHz; bandwidth (3 dB), 22 MHz.



(c) Filter type, six-section Chebyshev; center frequency, 130 MHz; bandwidth (3 dB), 21 MHz.

Figure 2. - FM receiver IF response.

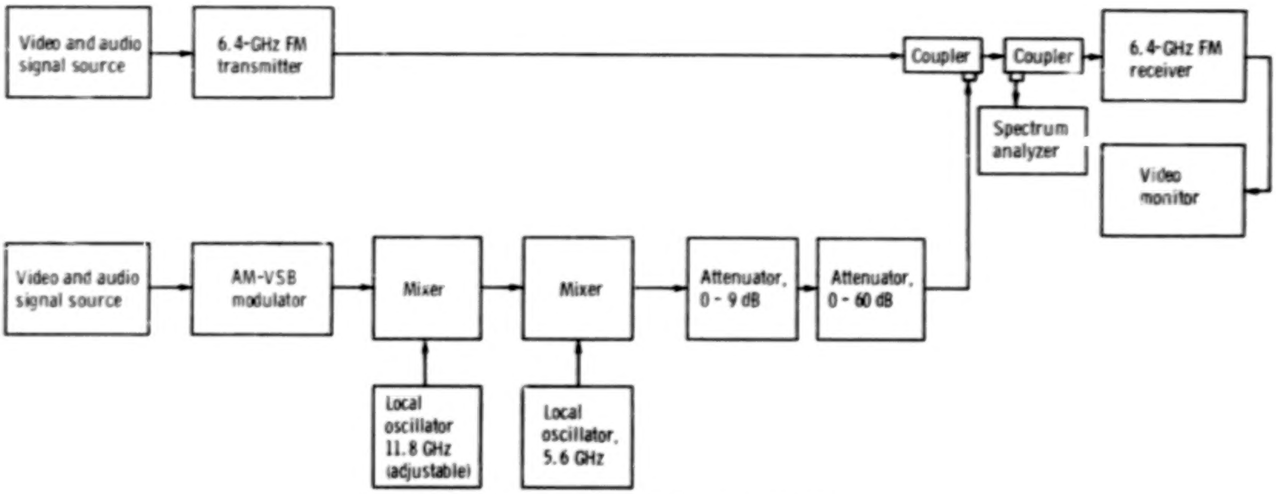


Figure 3. - AM television interfering with FM television.

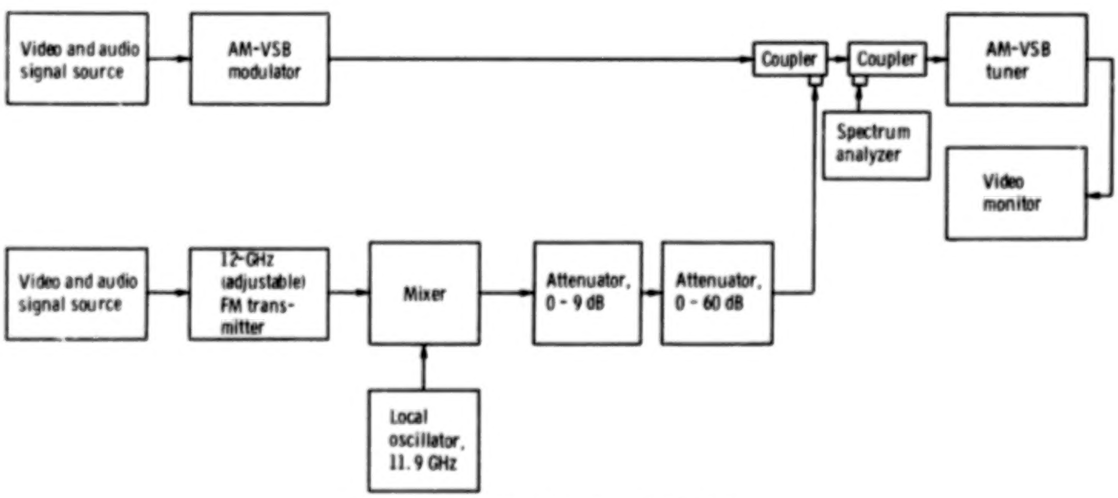


Figure 4. - FM television interfering with AM television.

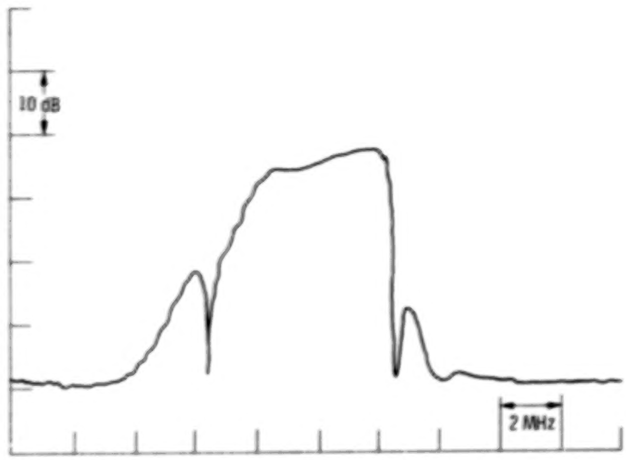
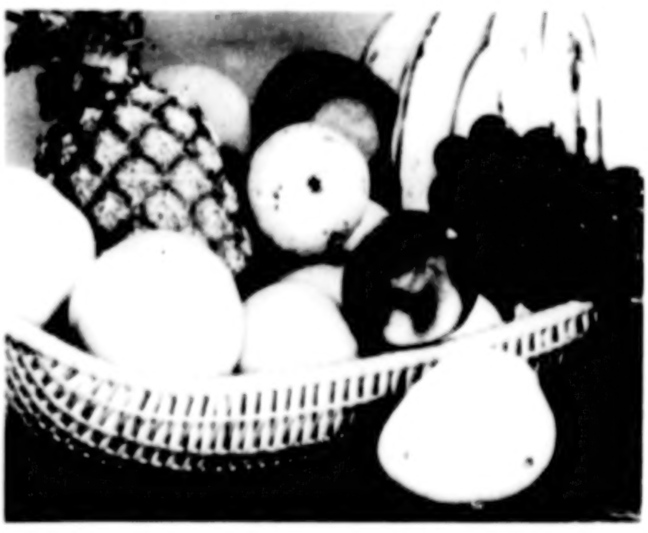


Figure 5. - AM receiver IF response. Center frequency, 45 MHz.

(a) SMPTE slide 1 - beach scene.

(b) SMPTE slide 14 - girl against plain background.



(c) Philips slide 8 - bowl of fruit.

(d) Philips slide 14 - make-up scene.

Figure 6. - Test slides.

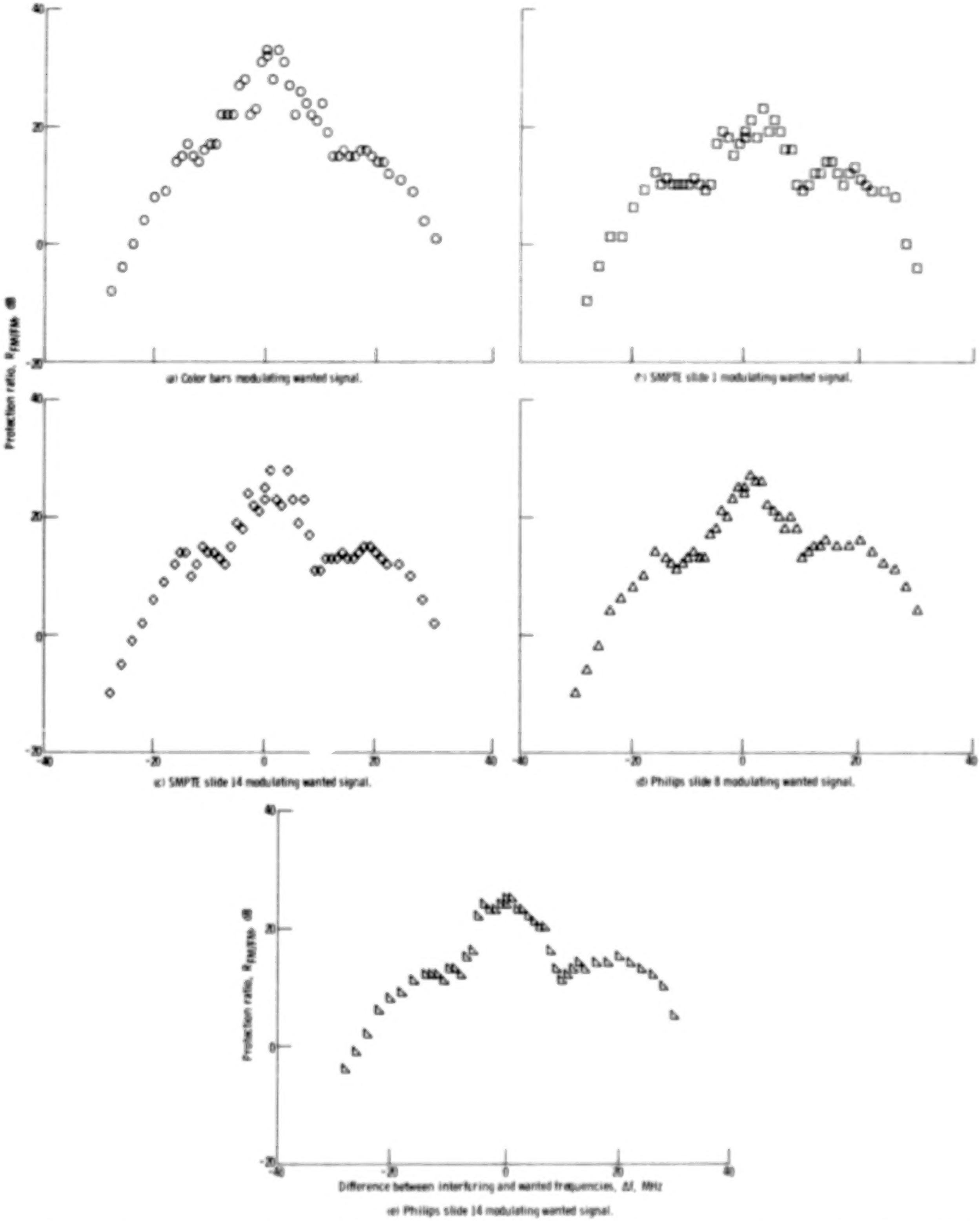


Figure 7. - Protection ratios required for just perceptible interference in FM system being interfered with by another FM television system. Peak-to-peak deviation, 18 MHz; type of filter, six section; intermediate frequency bandwidth (3 dB), 32 MHz.

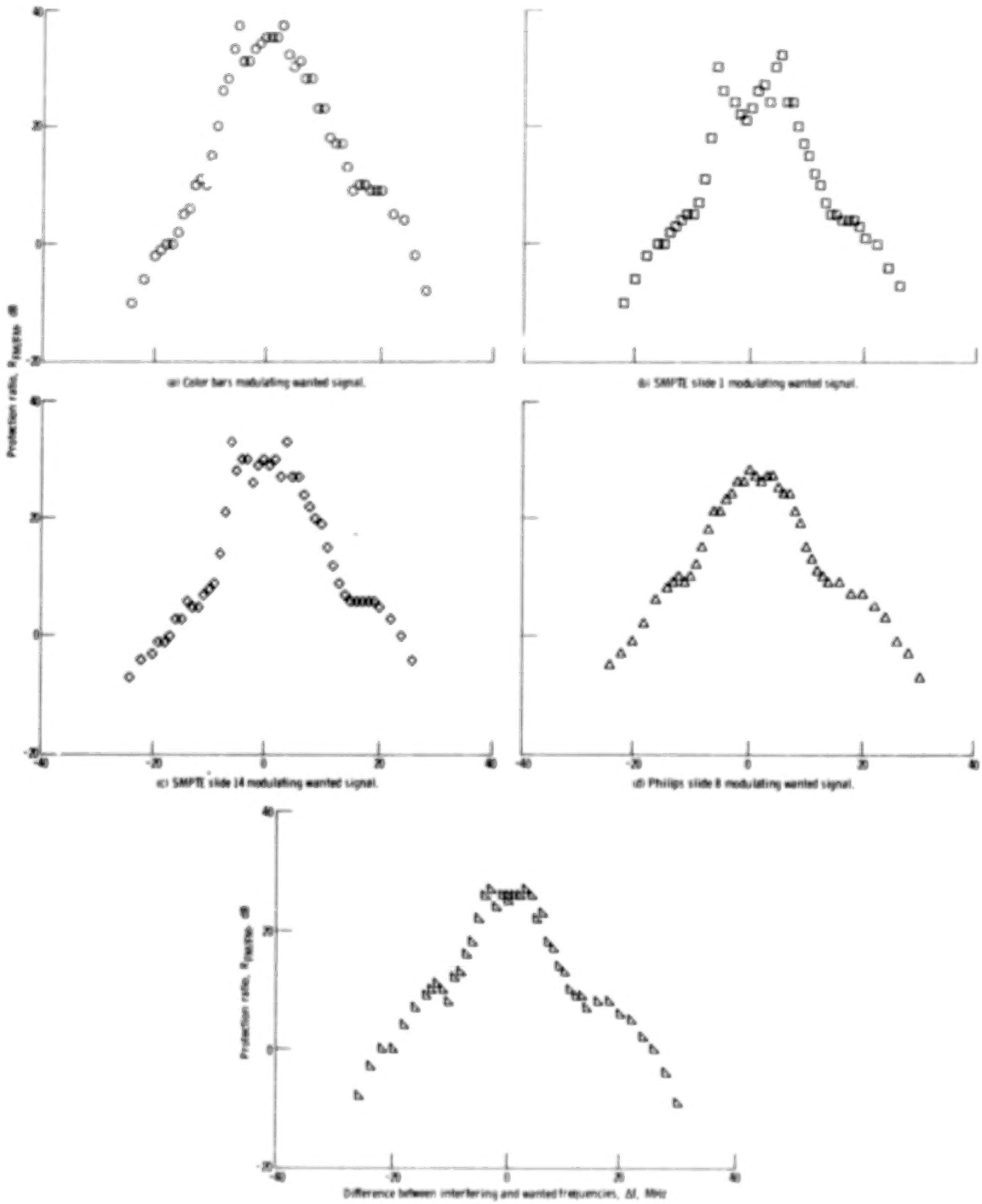
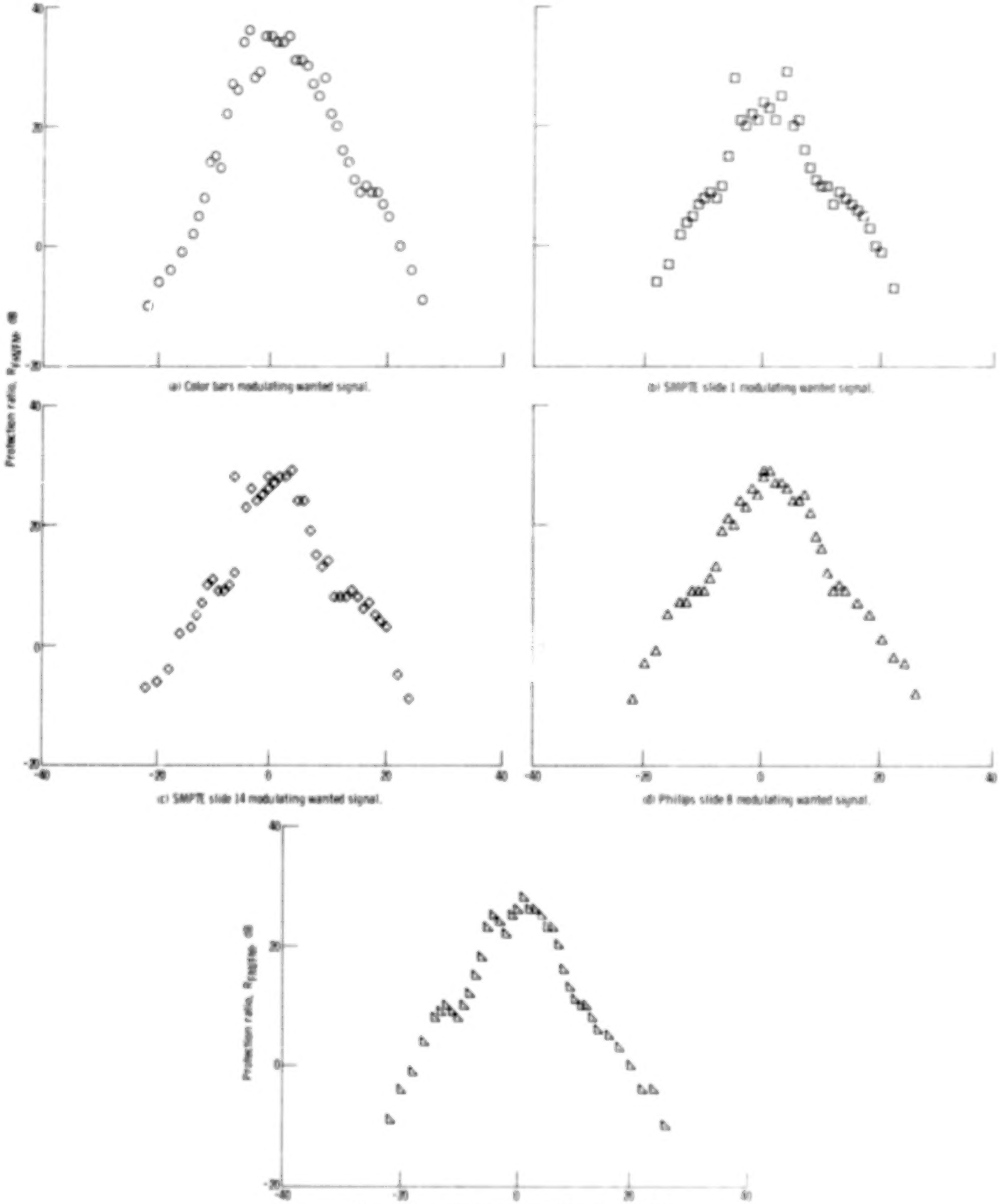


Figure 8. - Protection ratios required for just perceptible interference in FM system being interfered with by another FM television system. Peak-to-peak deviation, 12 MHz; type of filter, four section; intermediate frequency bandwidth (3 dB), 22 MHz.



(a) Color bars modulating wanted signal.

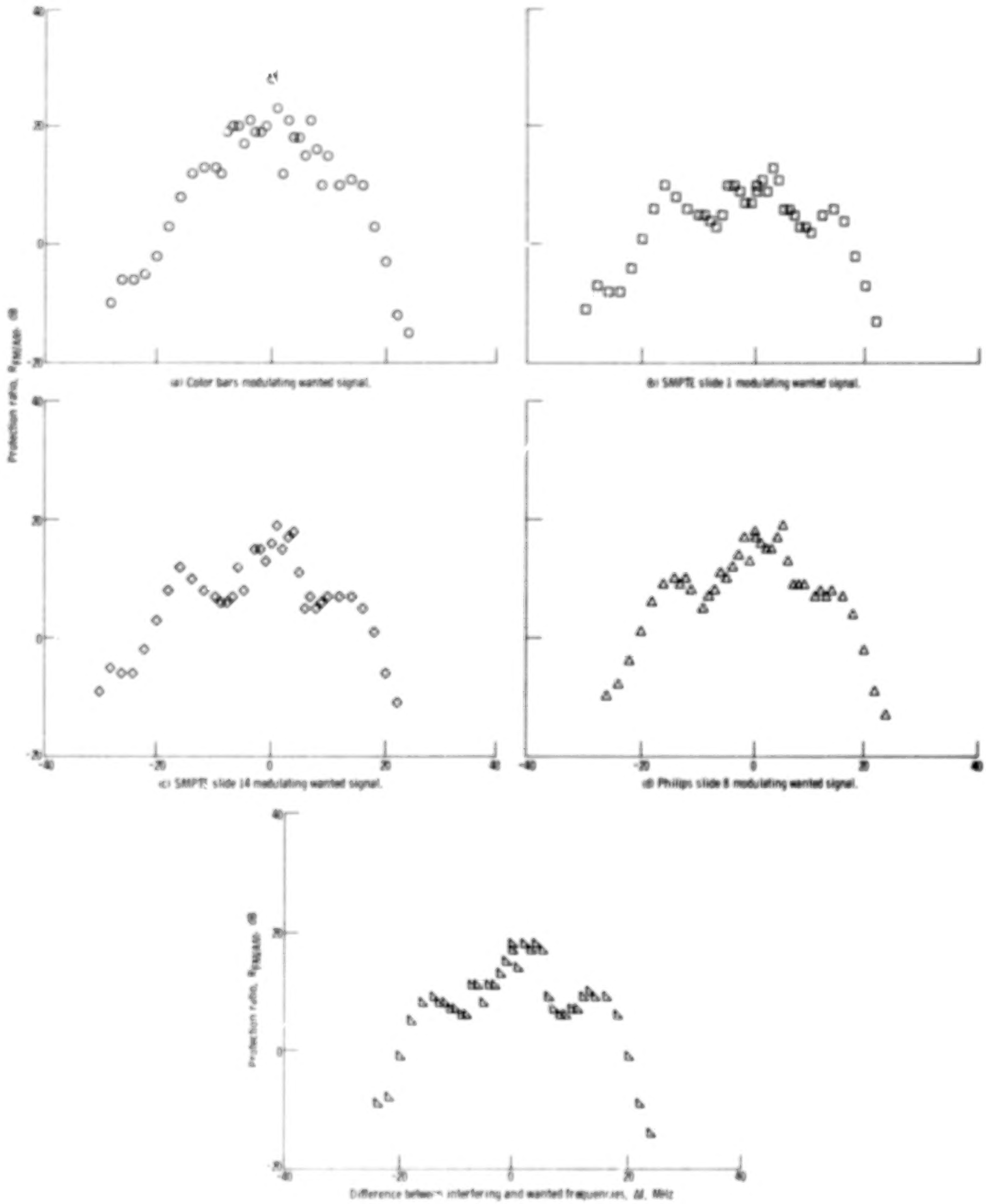
(b) SMPTE slide 1 modulating wanted signal.

(c) SMPTE slide 14 modulating wanted signal.

(d) Philips slide 8 modulating wanted signal.

(e) Philips slide 14 modulating wanted signal.

Figure 9. - Protection ratios required for just perceptible interference in FM system being interfered on by another FM television system. Peak-to-peak deviation, 12 MHz; type of filter, six section; intermediate frequency bandwidth (3 dB), 23 MHz.



(a) Color bars modulating wanted signal.

(b) SMPTE slide 1 modulating wanted signal.

(c) SMPTE slide 14 modulating wanted signal.

(d) Philips slide 8 modulating wanted signal.

(e) Philips slide 14 modulating wanted signal.

Figure 10. - Protection ratios require [illegible] ptible interference in FM system being interfered with by AM-VSB television system. Peak-to-peak deviation, 15 MHz; type of filter, six section; intermediate frequency ban [illegible] (B), 32 MHz.

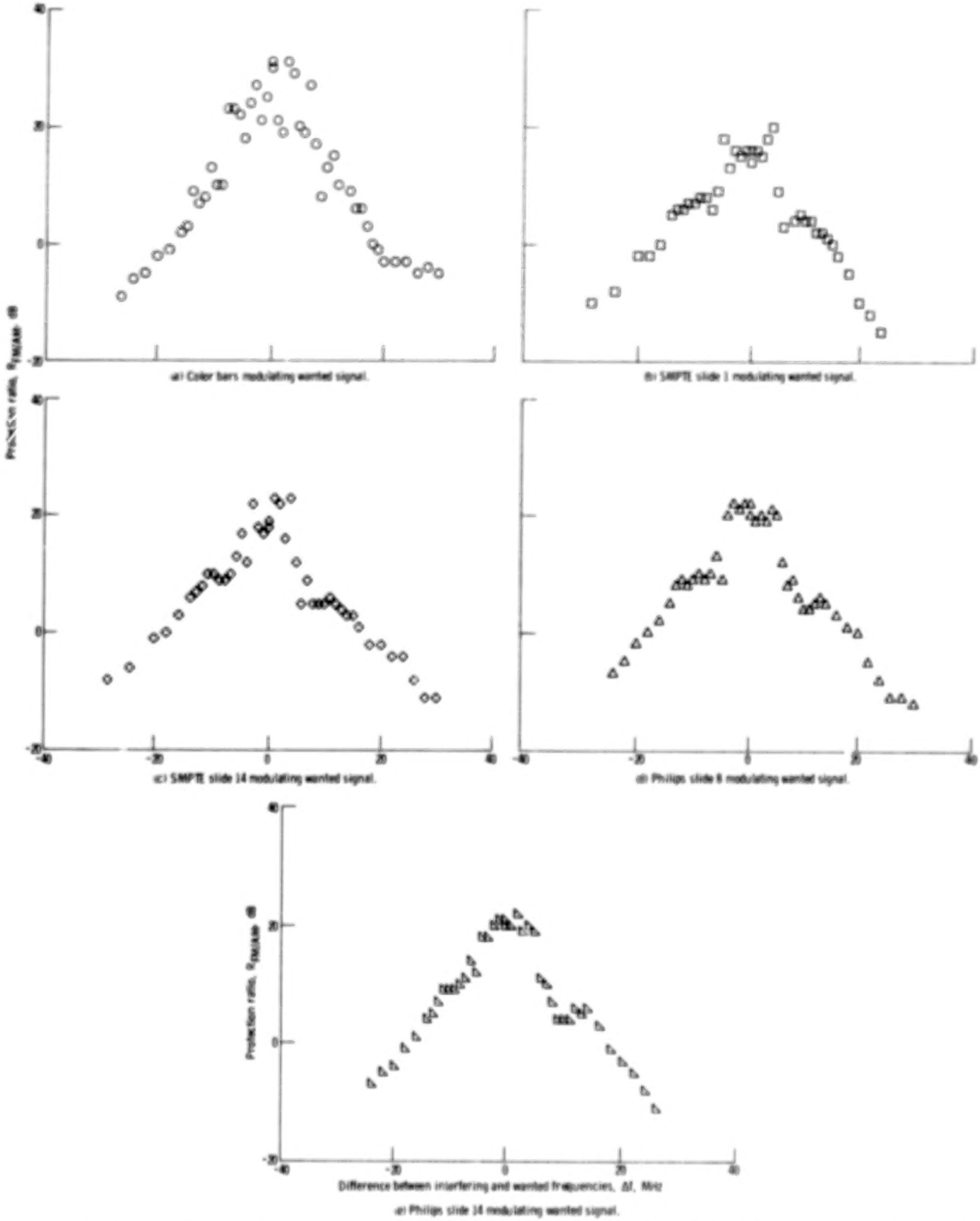


Figure 11. - Protection ratios required for just perceptible interference in FM system being interfered with by AM-VSB television system. Peak-to-peak deviation, 12 MHz, type of filter, four section; intermediate frequency bandwidth (3 dB), 22 MHz.

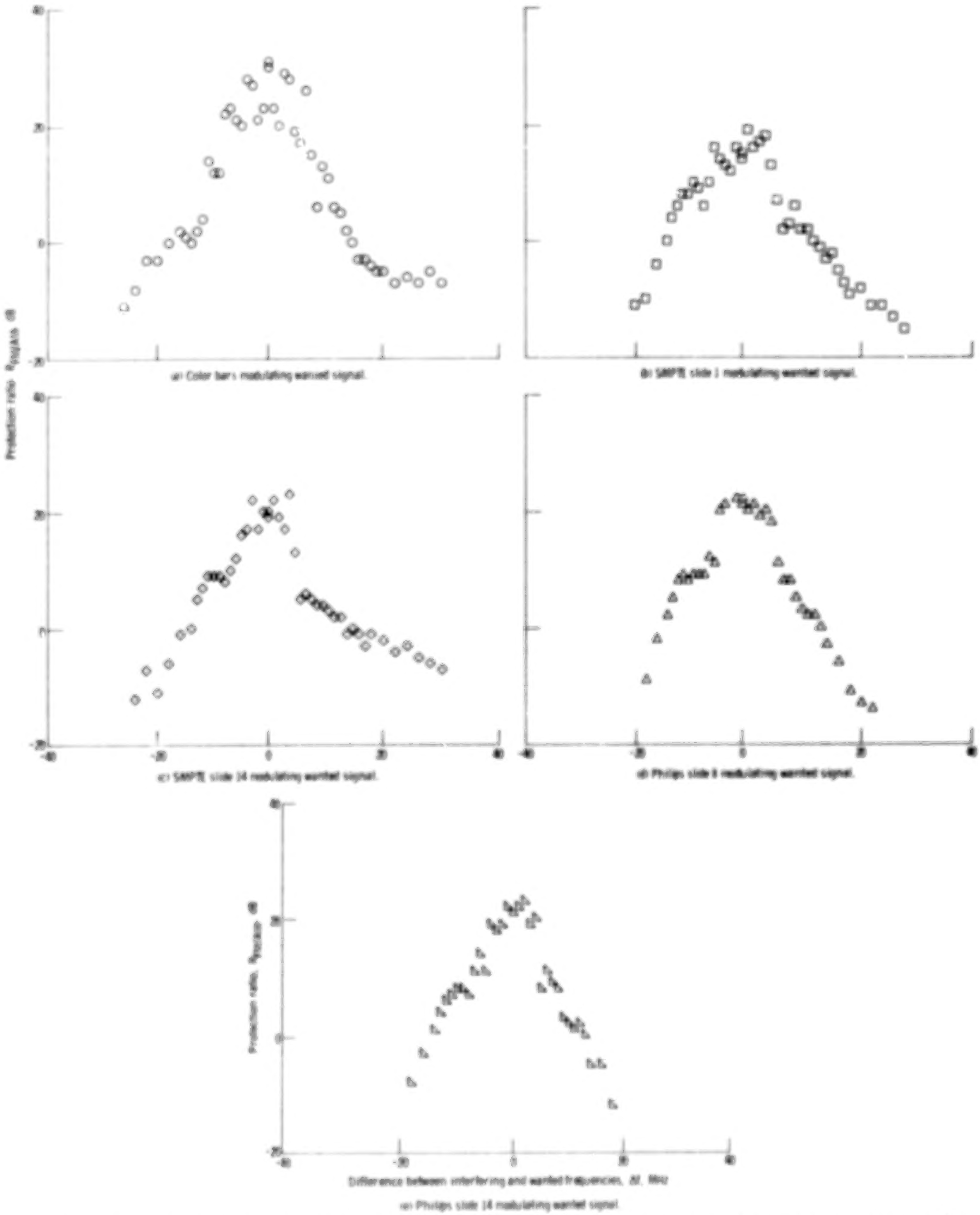


Figure 12. - Protection ratios required for just perceptible interference in FM system being interfered with by AM-VSB television system. Peak-to-peak deviation, 12 MHz; type of filter, six section; intermediate frequency bandwidth (3 dB), 21 MHz.

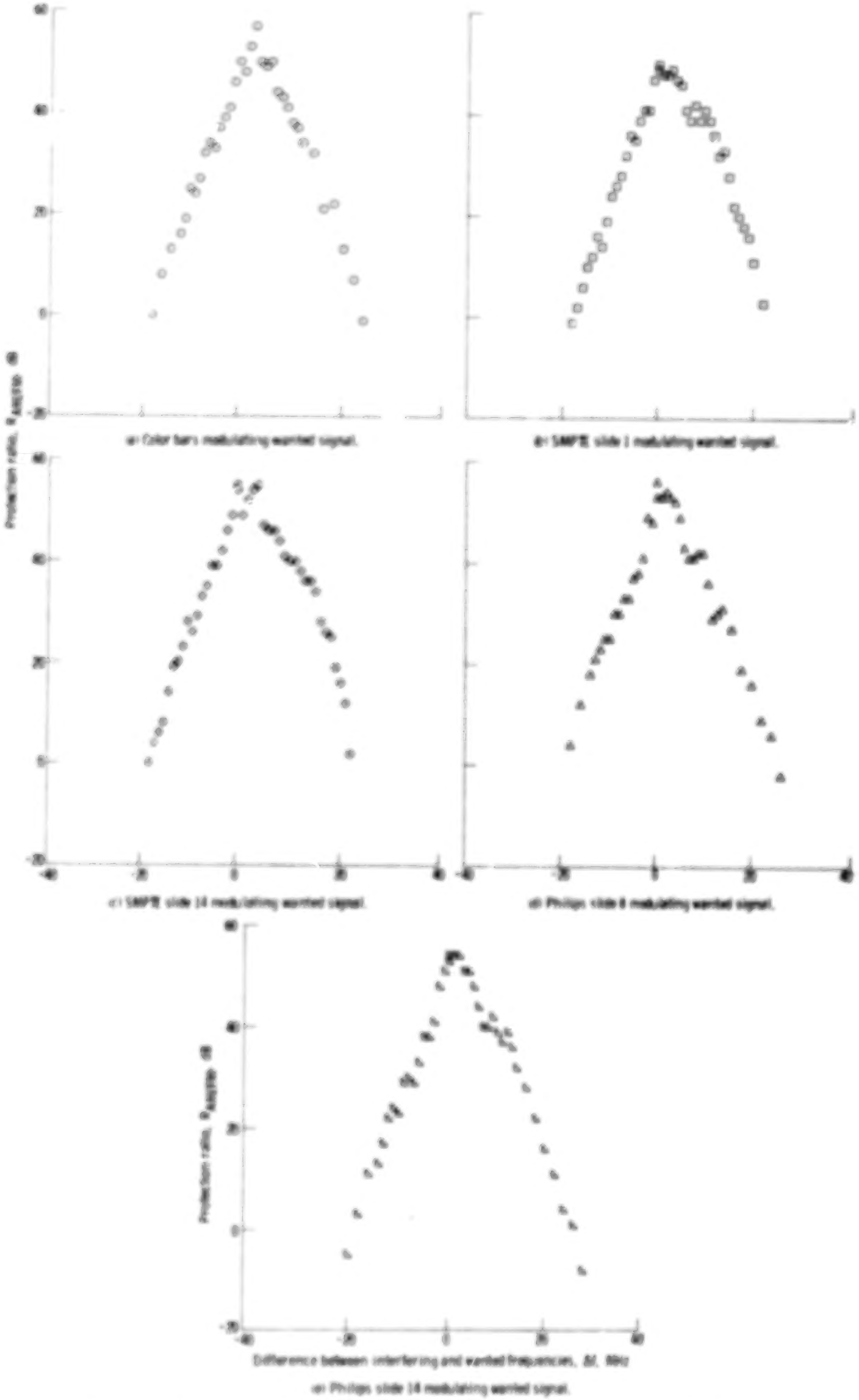


Figure 11. - Protection ratios required for just perceptible interference in AM VSB system being interfered with by FM television system. Peak-to-peak deviation, 16 MHz.

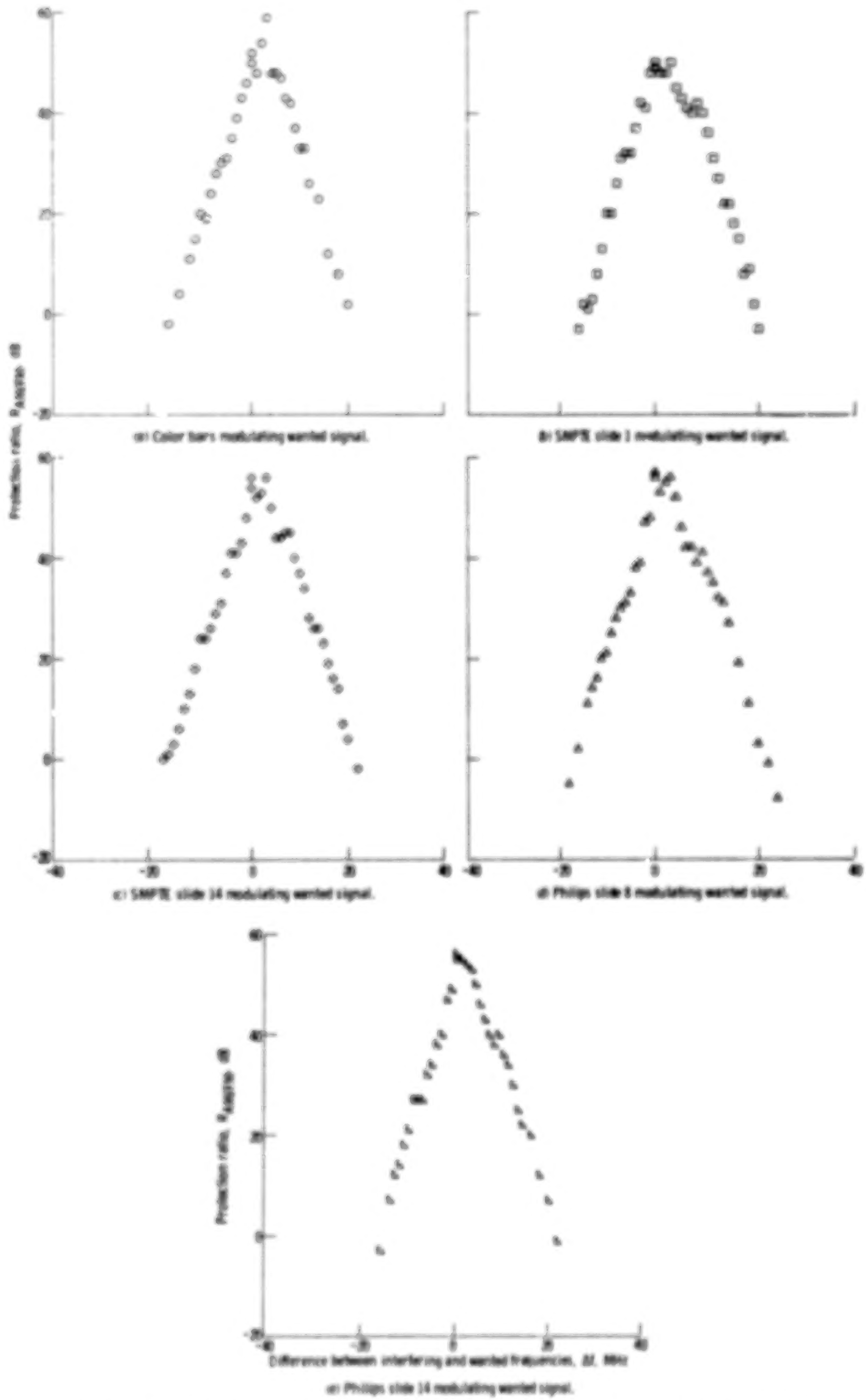


Figure 14. - Protection ratios required for just perceptible interference in AM-VSB system being interfered with by FM television system. Peak-to-peak deviation, 12 MHz.

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15. Supplementary Notes

16. Abstract

For just perceptible interference, an FM television signal interfering with another FM television signal should have an average signal power that is 26 to 37 dB less than the wanted signal power. For an AM-VSB television signal interfering with an FM television signal, the AM-VSB television's sync peak average power should be 18 to 31 dB below the FM television signal's average power. Also, when an FM television signal interferes with an AM-VSB signal, the average signal power of the FM signal should be 56 to 59 dB below the sync peak average power of the AM-VSB television signal. The range of power ratios occur as a result of different TV scenes used in the tests and different FM-signal frequency deviations used. All tests were performed using 525-line, system M, color-television signals, at the test conditions and using test slides suggested by the Consultative Committee on International Radio.

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